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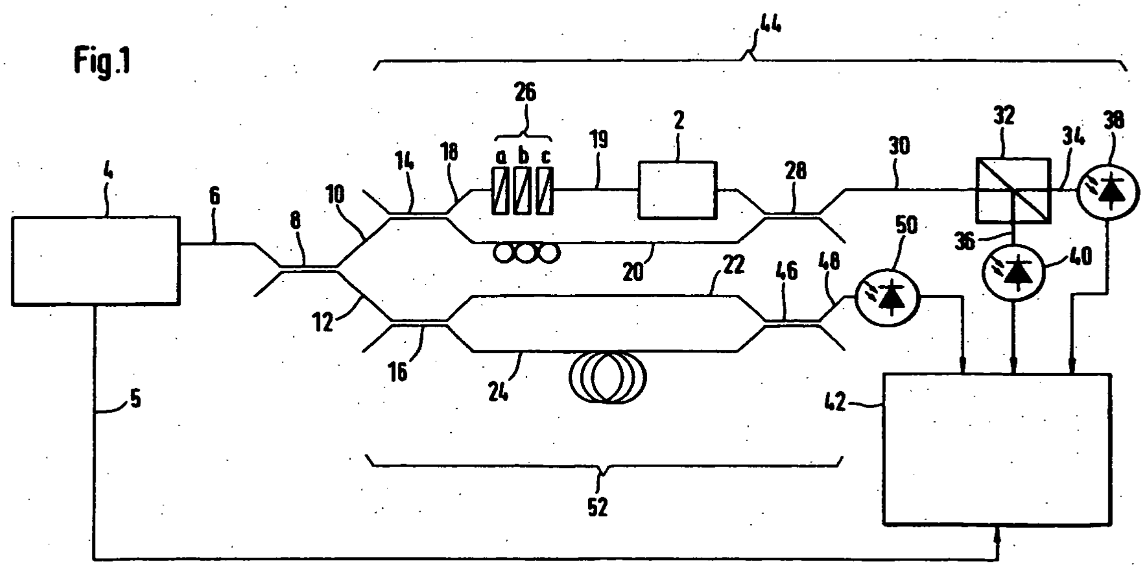
(54) **Method and apparatus for determining the polarisation mode dispersion of an optical device**

(57) A method and an apparatus for determination of properties, e.g. of elements of the Jones matrix, of an optical device under test, comprising the steps of: generating a coherent light beam, splitting the light beam into a first light beam and a second light beam, coupling the first light beam with a given initial polarization into the optical device under test, letting the second light beam travel a different path as the first light beam, superimposing the first light beam and the second light beam to generate interference between the first light beam and the second light beam in a resulting superimposed light beam, splitting the superimposed light beam into a third light beam polarization dependent and a fourth light beam, continuously detecting the power of the third and the fourth light beam as a function of frequency when tuning the frequency of the coherent light beam from a minimum to a maximum of a given frequency range, deriving transmissive properties, e.g. elements of the Jones matrix, from the frequency dependency of the detected power.

Fig.1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to the determination of properties of an optical device under test, e.g. the determination of the elements of the so-called Jones Matrix of an optical device.

[0002] The Jones matrix contains information about the polarization-mode dispersion (PMD) of the optical device under test, which can be a fiber or an optical component. PMD is a fundamental property of single-mode optical fibers and components in which signal energy at a given wavelength is resolved into two orthogonal polarization modes of slightly different propagation velocity. The resulting difference in propagation time between polarization modes is called the differential group delay (DGD). The term PMD is used to denote the physical phenomenon in general and the mean, or expected, value of DGD in particular. The attributes that define PMD are DGD, and the principal states of polarization (PSP). Both are generally functions of wavelength in single-mode fiber systems. In fibers that exhibit random coupling, PMD scales with the square root of fiber length. However, state of the art fibers may be limited to a few tenths of pico-seconds of DGD per root kilometer. Additionally, state of the art components for such fiber communication systems may exhibit only tenths of pico-seconds of DGD.

[0003] PMD causes a number of serious capacity impairments, including pulse broadening. In this respect, its effects resemble those of chromatic dispersion, but there is an important difference. Chromatic dispersion results from a variation in propagation delay with wavelength caused by the interplay of fiber material and dimensions, and is a relatively stable phenomenon. The total chromatic dispersion of a communications system can be calculated from the sum of its parts, and the location and value of dispersion compensatory can be planned in advance. In contrast, the PMD of single-mode optical fiber at any given signal wavelength is not stable, forcing communications system designers to make statistical predictions of the effects of PMD and making passive compensation impossible. Moreover, PMD becomes a limiting factor after chromatic dispersion has been sufficiently reduced. This is because the increasing bit rate of state of the art fiber communication systems, which bit rate reaches numbers of up to 40 GBit/s per channel, brings PMD, i.e. the mean value of DGD of the fiber over wavelength and time, also called the expected value, which mean value can reach 20 ps, in the range of the bit resolution of such a 40 GBit/s communication system.

[0004] Additionally, in state of the art communication systems components are often introduced in cascades, e.g. by introducing a cascade of a great number of Bragg-gratings in the fibers. Although the single component of such a cascade may exhibit only tenths of pico-seconds of DGD, the total cascade may exhibit DGDs that reach the resolution of the transmission rate. Therefore, it becomes more and more necessary to be able to gain exact information about the PMD of each single component.

[0005] The aforementioned problem has inspired the development of many measurement methods to measure PMD. In the following a few methods of the known methods shall be discussed.

[0006] In the fixed analyzer PMD measurement method, PMD is determined statistically from the number of peaks and valleys in the optical power transmission through a polarizer as wavelength is scanned. A polarizer placed directly before a detector is referred to as an analyzer, hence the name of the method. The fixed analyzer response may be Fourier transformed to yield a spectrum that gives insight into the degree of mode coupling and allows calculation of PMD from a Gaussian fit or from the second-moment algorithm. The problem with the fixed analyzer method is that it is not possible to measure the PMD of components that exhibit bandwidths that are smaller than the variation in the optical power transmission over wavelength.

[0007] Another method is the interferometric method, which determines PMD from the electric field auto-correlation function using a broadband source. The value of PMD is computed with an algorithm based on the second moment. The problem of this method is that it only generates exact values of PMD when the PMD is caused by pure birefringence. However, this method is not able to produce useful PMD values when the PMD is wavelength-dependent.

[0008] Another method is the so called Poincaré arc or SOP (state of polarization) method, which method uses a polarimeter to capture the arc traced out on the Poincaré sphere by the output polarization of the test device over a series of wavelength increments. However, if the polarized light is coupled accidentally into the main state of polarization of the test device, PMD cannot be measured. Another problem is that a high-resolution polarimeter is necessary which kind of polarimeters tend to be very expensive. Moreover, with this method chromatic dispersion cannot be measured.

[0009] Another method is the so-called Jones matrix eigen-analysis or JME method. This method determines DGD and PSP as functions of wavelength from measurements of the transmission matrix at a series of wavelengths. Again, this method uses an expensive polarimeter. This method also does not give information about chromatic dispersion.

[0010] Finally, there are methods known which measure PMD more or less on a direct way. These methods, e.g. the modulation phase method and the pulse-delay methods determine PMD from measurements of the change in modulation phase and the change in pulse arrival time, respectively, between the principle states of polarization. The drawback of these methods is the pulse shape dependency of the results.

SUMMARY OF THE INVENTION

[0011] It is an object of the invention to provide an improved determination of properties of an optical device under test, and preferably to provide starting values for calculating PMD allowing to avoid at least some of the aforementioned problems. The objects are solved by the independent claims.

[0012] An advantage of the present invention is the possibility of deriving transmissive properties, e.g. the PMD of the device under test (DUT) just by determining the elements of the Jones matrix of the DUT without need to make use of an expensive polarimeter, and the possibility of simultaneously measuring the chromatic dispersion of the DUT. Moreover, it is possible to derive additional information from the derived Jones Matrix of the DUT, since the Jones matrix contains also information about the principle states of polarization (PSP) and the polarization dependent loss (PDL) of the DUT. So, all the above-mentioned problems in the prior art can be avoided by the present invention.

[0013] The term "coherent" in this application means that the coherence length of the light beam is larger than the difference of lengths of the paths of the first and second and the fifth and sixths light beams, respectively.

[0014] In a preferred embodiment of the invention, the apparatus contains a first Mach-Zehnder interferometer whereby a polarization setting tool is placed in the measurement arm, so that the laser light couples into the DUT with a defined polarization. This direction of polarization is then defined as the x-axis of the coordinate system of the Jones matrix calculus. Accordingly, the first two elements of the Jones matrix can easily be derived. In a second run of the inventive method, the other two elements of the Jones matrix are derived with the same interferometer by changing the direction of polarization of the light beam incident on the DUT. It is preferred for easy evaluation of the results to change the polarization to a polarization orthogonal with respect to the former polarization. In this respect, it is further preferred that the initial polarization is linear and the changed polarization is changed by 90° with respect to the initial polarization.

[0015] In another preferred embodiment, there is a second Mach-Zehnder interferometer parallel to the first one. In this second interferometer the same coherent laser beam of the laser source is coupled in by a beam splitter before these two interferometers. With the help of the second interferometer, which is a reference interferometer without an optical device in its measurement arm, any non-linearities in the detected powers of the resulting beams of the first interferometer caused by a non-linearity in the scanning velocity when scanning the frequency of the laser frequency can be eliminated.

[0016] Other preferred embodiments are shown by the dependent claims.

[0017] It is clear that the invention can be partly or entirely embodied or supported by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable data processing unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawings. The components in the drawings are not necessarily to scale, emphasizes instead being placed upon clearly illustrating the principles of the present invention. Features that are substantially or functionally equal or similar will be referred to with the same reference sign(s).

Fig. 1 shows a schematic illustration of an embodiment of the apparatus of the invention;

Fig. 2 shows two graphs comparing PSP group delay with DGD; and

Fig. 3 shows two graphs comparing PSP group delay with DGD without a device under test.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Referring now in greater detail to the drawings, Fig. 1 shows a schematic illustration of a preferred embodiment of an apparatus 1 for interferometric determination of the frequency-dependent Jones matrix of a two port optical transmission device under test (DUT) 2, according to the present invention. The apparatus 1 according to Fig. 1 and the respective method as described in the following is contemplated by the inventor as the best mode of carrying out the invention. By means of the apparatus 1 shown in Fig. 1 the DUT 2, which is an optical component and can be a fiber, a Bragg-grating or any other optical component or even air, is to be characterized in terms of its chromatic dispersion and its PMD.

[0020] The apparatus 1 comprises as a signal source a tunable laser 4, which can be continuously tuned in respect of frequency. The laser 4 emits a coherent laser beam 6. The laser beam 6 is coupled into a first beam splitter 8 which

splits the coherent laser beam 6 in a first beam 10 and a second beam 12. The first beam 10 is coupled into a second beam splitter 14. The second beam 12 is coupled into a third beam splitter 16. The second beam splitter 14 splits the first laser beam 10 into a third laser beam 18 and a fourth laser beam 20. The third beam splitter 16 splits the second laser beam 12 into a fifth laser beam 22 and a sixth laser beam 24.

[0021] The third laser beam 18 is coupled into a polarization controller 26 (which can be a Hewlett-Packard HP8169A) with three sub-units 26a, 26b and 26c. After passing the polarization controller 26, the laser beam (now denoted by 19) is polarized and coupled into the DUT 2. After passing the DUT 2, the polarized laser beam 19 is reunited with the fourth laser beam 20. The fourth laser beam 20 has traveled a different optical distance (e.g. several meters) compared to the third laser beam 18 and the polarized laser beam 19 from the second beam splitter 14 to the fourth beam splitter 28.

[0022] At the fourth beam splitter 28, the polarized laser beam 19 and the fourth laser beam 20 are superimposed to produce interference between the polarized laser beam 19 and the fourth laser beam 20, resulting in the first superimposed laser beam 30. The first superimposed beam 30 is then coupled into a polarization beam splitter 32, which splits the beam 30 into a seventh beam 34 and an eighth beam 36. Beam 34 is then coupled into a first photodiode 38. The beam 36 is coupled into a second photodiode 40. Polarization beam splitter 32, first photodiode 38, and second photodiode 40 provide a polarization diversity receiver. First photodiode 38 and second photodiode 40 transmit their outputs to an analog/digital-converter (ADC) 42 (which can be a National Instruments AT-MIO-16DE-10) connected to an evaluation unit (not shown) to evaluate the detected data.

[0023] Second beam splitter 14, third laser beam 18 and polarized laser beam 19, fourth laser beam 20 and fourth beam splitter 28 provide a Mach-Zehnder interferometer 44. The third laser beam 18 and the polarized laser beam 19 provide a measurement arm of the Mach-Zehnder interferometer 44. The fourth laser beam 20 provides a reference arm of the Mach-Zehnder interferometer 44. The DUT 2 is disposed in the measurement arm of the Mach-Zehnder interferometer 44.

[0024] The fifth laser beam 22 and the sixth laser beam 24 travel a different optical distance before they are superimposed with a fifth beam splitter 46. Exiting the fifth beam splitter 46 is a second superimposed beam 28, which is detected by a third photodiode 50. The third photodiode 50 outputs a respective signal to the analog/digital-converter (ADC) 42. The third beam splitter 16, the fifth laser beam 22, the sixth laser beam 24 and the fifth beam splitter 46 provide a reference interferometer 52 to the measurement interferometer 44. This reference interferometer 52 helps as a part of apparatus 1 eliminating possible non-linearity in time of the tuning gradient of the tuning of the frequency of the laser 4. For this purpose the output of the photodiode 50 is an input of ADC 42.

[0025] ADC 42 thereby gets information about occurrence of any non-linearity of the scan-velocity of the laser 4. Based on this information this non-linearity can be subtracted by the evaluation unit from the results of the measurements of the measurement interferometer 44.

[0026] The tunable laser 4 has a trigger output 5, which is input into the ADC 42 for triggering the ADC 42.

[0027] A preferred embodiment of the inventive method works as following. By the polarization controller 26 the third laser beam 18 gets a defined polarization, resulting in the polarized laser beam 19. With this defined polarization the polarized laser beam 19 is coupled into the DUT 2. After passing the DUT 2 the polarized laser beam 19 is superimposed with the fourth laser beam 20, i.e. the reference arm of the Mach-Zehnder interferometer 44. The resulting first superimposed beam 30 is then coupled into the polarization beam splitter 32 which results in the seventh laser beam 34 and the eighth laser beam 36 which have two orthogonal output polarizations in terms of magnitude and phase. These orthogonal polarized beams 34 and 36 are detected by the photodiodes 38 and 40 and the respective output signals of the photodiodes 38 and 40 are received by the ADC 42. With the signals received by the ADC 42 the evaluation unit is able to determine with the calculus described below the transmission function of the DUT 2 in regard to two orthogonal output polarizations in terms of magnitude and phase. That gives two elements of the Jones matrix of the DUT 2 by following the calculus described below.

[0028] The missing two elements of the Jones matrix of the DUT 2 are obtained by changing the polarization of the polarized laser beam 19 with the polarization controller 26 and performing the aforementioned steps of the inventive method in a second run of the method. The changed polarization of the thus resulting polarized laser beam (not shown) is preferably orthogonal to the polarization of the polarized laser beam 19 in the first run of the method. Thereby, it is possible to calculate the missing two elements of the Jones matrix of the DUT 2. Having the complete Jones matrix it is then very easy to derive DGD, PMD, PSP, PDL or chromatic dispersion of the DUT 2.

[0029] To explain the determination of the differential group delay (DGD) by means of the Jones matrix, the following explanations show the used calculus to perform this determination.

[0030] The Jones Matrix U provides the relationship between the Jones vectors at the input $\vec{E}_a$ and at the output $\vec{E}_b$ of the DUT 2:

$$\vec{E}_b = U(\omega)\cdot\vec{E}_a$$

[0031] Generally, the Jones matrix describes a birefringent element that at an optical frequency ω has two main axes with which two differential group delays $\tau_\pm$ can be associated. The associated input and output polarization states are also referred to as main states or principal states of polarization (PSP). Now, using $U(\omega)$ the differential group delay (DGD) between the principal axes is to be determined. If $\vec{E}_{a\pm}$ and $\vec{E}_{b\pm}$ are the (still unknown) principal states at the input and the output of DUT 2, respectively, it is possible to establish the following relationship:

$$\vec{E}_{b\pm} = e^{+j\tau\pm\omega} \cdot U \cdot \vec{E}_{a\pm}$$

[0032] $\vec{E}_{a\pm}$ and $\vec{E}_{b\pm}$ are to be standardized in such a way that their mean phase disappears: $Im\{E_x \cdot \vec{E}^*_y\}=0$. The principal states are in a first approximation independent of frequency. Therefore the following applies:

$$\frac{d\vec{E}_{b\pm}}{d\omega} = j\tau_\pm \cdot U \cdot \vec{E}_{a\pm} + e^{j\tau_\pm\omega} \cdot \dot{U} \cdot \vec{E}_{a\pm} \overset{!}{=} 0$$

[0033] Conversion gives a generalized eigen-value problem:

$$\dot{U} \cdot \vec{E}_{a\pm} = j \cdot e^{j\tau\pm\omega} \cdot \tau_\pm \cdot U \cdot \vec{E}_{a\pm}$$

[0034] The eigen-values give:

$$\lambda_\pm = j \cdot e^{j\tau\pm\omega} \cdot \tau_\pm$$

[0035] Taking the magnitude of the eigen-values, it is possible to calculate the differential group delay of the two principal states, and thus the DGD:

$$\tau_\pm = |\lambda_\pm| \text{ , } DGD=\tau_+-\tau$$

[0036] In order to be able to determine the Jones Matrix U, it is necessary (see above) to carry out two partial measurements with respectively orthogonal input polarizations E_{a1} and $\vec{E}_{a2}$ of the polarized laser beam 19. If those two input polarizations are used as base vectors for the Jones representation, then that would correspond to the following input vectors:

$$\vec{E}_{a1} = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \cdot E_0 \quad , \quad \vec{E}_{a2} = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \cdot E_0$$

[0037] The corresponding output vectors read as follows:

$$\vec{E}_{b1} = \begin{pmatrix} u_{11} \\ u_{21} \end{pmatrix} \cdot E_0 \quad , \quad \vec{E}_{b2} = \begin{pmatrix} u_{21} \\ u_{22} \end{pmatrix} \cdot E_0$$

[0038] The symbols u_{mn} in that case denote the four elements of the Jones matrix. The light 20 coming from the reference arm can be described by the following Jones vector:

$$\vec{E}_r = \begin{pmatrix} \cos\varphi \cdot e^{-j\phi} \\ \sin\varphi \cdot e^{+j\phi} \end{pmatrix} \cdot e^{-j\tau_r\omega} \cdot E_0$$

[0039] In that case, τ_r denotes the group delay of the reference arm 20. For the sake of simplicity, it will be assumed hereinafter that the power is uniformly distributed to the two base states and there is not a relative phase difference between them (linearly polarized light is incident at 45° on the polarization beam splitter 32):

$$\vec{E}_r = \begin{pmatrix}1\\1\end{pmatrix}\frac{1}{\sqrt{2}}e^{-j\tau_r\omega}\cdot E_0$$

[0040] The light incident on the detectors then affords, by virtue of superimposition with the measurement signal:

$$\vec{E}_{Det1} = \begin{pmatrix}E_{Det11}\\E_{Det21}\end{pmatrix} = \begin{pmatrix}u_{11} + \frac{1}{\sqrt{2}}e^{-j\tau_r\omega}\\u_{21} + \frac{1}{\sqrt{2}}e^{-j\tau_r\omega}\end{pmatrix}\cdot E_0$$

$$\vec{E}_{Det2} = \begin{pmatrix}E_{Det12}\\E_{Det22}\end{pmatrix} = \begin{pmatrix}u_{12} + \frac{1}{\sqrt{2}}e^{-j\tau_r\omega}\\u_{22} + \frac{1}{\sqrt{2}}e^{-j\tau_r\omega}\end{pmatrix}\cdot E_0$$

with

$$u_{mn} = U_{mn}e^{j\varphi_{mn}}$$

the following applies in regard to the detector powers:

$$P_{mn} \sim |E_{Det,mn}|^2 / E_0 = \frac{1}{2} + U^2{}_{mn} + \sqrt{2}U_{mn}\cos(\varphi_{mn} + \tau_r\omega)$$

[0041] On the assumption that the magnitude U_{mn} changes markedly more slowly with frequency than the term cos ($\varphi_{mn} + \tau_r\omega$), it is possible to determine both $U_{mn}(\omega)$ and also $\varphi_{mn}(\omega)$ from the interference signal present at the detectors 38, 40. It is possible numerically to calculate the derivation $U(\omega)$ from the matrix $U(\omega)$ and to derive therefrom as described above the DGD.

[0042] In the case of real measurements errors occur in particular in determining the absolute phase terms of $U(\omega)$. In that respect it can happen that the light of the reference arm 20 meets the polarization beam splitter 32 not linearly but elliptically ($\phi \neq 0$). In addition it is problematical that the measurement is composed of two wavelength scans of the laser source 4. Due to this uncertainty, there is a phase error φ_a in the first column of the Jones Matrix U and φ_b in the second column. Instead of the matrix U the matrix $\tilde{U}$ is measured:

$$\tilde{U} = \begin{pmatrix}e^{j\phi} & 0\\0 & e^{-j\phi}\end{pmatrix}\cdot U\cdot\begin{pmatrix}e^{j\varphi_a} & 0\\0 & e^{j\varphi_b}\end{pmatrix}$$

[0043] As that is equivalent to an upstream-connected or downstream-connected polarization controller 26, this does not change anything in regard to the DGD derived therefrom. The resulting principal states however are different. No further corrections are therefore required to determine the DGD.

[0044] As a first attempt, the above-described method was used as described above by the inventor with the apparatus of Fig. 1 to measure as a DUT 2 a highly birefringent fibre (HiBi-fibre). The results can be seen in Fig. 2.

[0045] In Fig. 2 the upper plot shows the group delay of the two principal axes. The abscissa shows the wavelength in nm and the ordinate shows the group delay in ps. The lower plot shows the difference between the two group delays, the DGD in ps over the wavelength in nm. It can be seen that the DGD is very good at 10 ps while the absolute values fluctuate greatly over wavelength. One reason for this could be Fabry-Perot interference in the free-beam optical polarization controller 26 which was present in the measurement arm in addition to the DUT (see Fig. 1). It is possible under some circumstances to place the polarization controller 26 upstream of the second beam splitter 14 so that group delay fluctuations do not play any part. That however also has effects on polarization in the reference arm 20, which possibly has to be corrected.

[0046] Fig. 3 shows a measurement with the above-described method without DUT 2 in the apparatus of Fig. 1:

[0047] In Fig. 3 the upper plot shows the group delay of the two principal axes. The abscissa shows the wavelength in nm and the ordinate shows the group delay in ps. The lower plot shows the difference between the two group delays, the DGD in ps over the wavelength in nm. As expected the DGD is closer to zero. Marked deviations from the ideal value however can be seen, which permits an assessment of the measurement accuracy of the apparatus 1 of the present invention of a few pico-seconds.

Claims

1. A method of determination of properties of an optical device under test (2), comprising the steps of:

    - generating a coherent light beam (6),
    - splitting the light beam (6) into a first light beam (18, 19) and a second light beam (20),
    - coupling the first light beam (18, 19) with a given initial polarization into the optical device under test (2),
    - letting the second light beam (20) travel a different path as the first light beam (18, 19),
    - superimposing the first (18, 19) and the second light beam (20) to generate interference between the first light beam (18, 19) and the second light beam (20) in a resulting superimposed light beam (30),
    - splitting the superimposed light beam (30) polarization-dependent into a third light beam (34) and a fourth light beam (36),
    - continuously detecting the power of the third light beam (34) and the fourth light beam (36) as a function of frequency when tuning the frequency of the coherent light beam (6) from a minimum to a maximum of a given frequency range, and
    - deriving transmissive properties of the optical device under test from the frequency dependency of the detected powers.

2. The method of claim 1, further comprising the step of:

    - deriving elements of the Jones matrix for the optical device under test from the frequency dependency of the detected powers.

3. The method of claim 1 or 2, further comprising the steps of:

    - changing the initial polarization of the first light beam (18, 19) with respect to said given initial polarization into a changed polarization,
    - performing the steps of claim 1 a second time with said changed polarization.

4. The method according to claim 1 or any one of the above claims, further comprising the step of:

    - polarizing the first light beam (18, 19) after splitting the coherent light beam (6).

5. The method according to claim 1 or any one of the above claims 2 - 3, further comprising the step of:

    - polarizing the coherent light beam (6) before splitting it.

6. The method according to claim 3 or any one of the above claims 4 - 5, further comprising the step of:

    - changing the initial polarization of the first light beam (18, 19) into an orthogonal polarization.

7. The method according to claim 3 or any one of the above claims 4 - 6, further comprising the step of:

- making the given initial polarization a linear polarization.

8. The method according to claim 3 or any one of the above claims 4 - 7, further comprising the steps of:

- splitting the coherent light beam (6) into a first initial light beam (10) and a second initial light beam (12),

- performing the steps of claim 1 with said first initial light beam (10),

- splitting the second initial light beam (12) in a fifth light beam (22) and a sixth light beam (24),

- superimposing the fifth (22) and the sixth light beam (24) after each light beam (22, 24) has traveled a different path, to generate interference between the fifth (22) and the sixth light beam (24) in a resulting superimposed light beam (48),

- continuously detecting the power of the resulting superimposed light beam (48) as a function of frequency when tuning the frequency of the coherent light beam (6) from a minimum to a maximum of a given frequency range,

- detecting a non-linearity in a tuning gradient frequency when tuning the frequency of the coherent light beam (6) from the minimum to the maximum of the given frequency range,

- when detecting a non-linearity, using said detected non-linearity information to compensate effects on the detected powers of the third (34) and the fourth light beam (36) caused by said non-linearity.

9. The method according to claim 3 or any one of the above claims 4 - 8, further comprising at least one of the following steps:

- deriving the polarization mode dispersion (PMD) of the device under test (2) from the derived Jones matrix elements of the device under test (2),

- deriving the chromatic dispersion of the device under test (2) from the derived Jones matrix elements of the device under test (2),

- deriving the principal states of polarization (PSP) of the device under test (2) from the derived Jones matrix elements of the device under test (2),

- deriving the polarization dependent loss (PDL) of the device under test (2) from the derived Jones matrix elements of the device under test (2).

10. A software program or product, preferably stored on a data carrier, for executing the method according to claim 1 or any one of the above claims, when run on a data processing system such as a computer.

11. An apparatus for determination of properties of an optical device under test (2), comprising:

a first beam splitter (14) in said path splitting a coherent light beam (6) into a first light beam (18, 19) travelling a first path and a second light beam (20) travelling a second path, whereby the optical device under test (2) is arranged in said first path for coupling in the first light beam (18, 19) with a given initial polarization,

a second beam splitter (28) in said first and in said second path for superimposing the first (18, 19) and the second light beam (20) after the second light beam (20) has traveled a different path as the first light beam (18, 19), to generate interference between the first light beam (18, 19) and the second light beam (20) in a resulting superimposed light beam (30) travelling a resulting path,

a polarization beam splitter (PBS) (32) in said resulting path for splitting the superimposed light beam (30) polarization dependent into a third light beam (34) travelling a third path and a fourth light beam (36) travelling a fourth path,

a first power detector (38) in said third path for continuously detecting the power of the third light beam (34)

as a function of frequency when tuning the frequency of the coherent light beam (6) from a minimum to a maximum of a given frequency range,

a second power detector (38) in said fourth path for continuously detecting the power of the fourth light beam (36) as a function of frequency when tuning the frequency of the coherent light beam (6) from a minimum to a maximum of a given frequency range,

an evaluation unit for deriving transmissive properties of the optical device under test (2) from the frequency dependency of the detected powers.

12. The apparatus of claim 11,
comprising an evaluation unit for deriving elements of the Jones matrix of the optical device under test (2) from the frequency dependency of the detected and converted powers.

13. The apparatus of claim 11 or 12,
wherein the first beam splitter (14), the second beam splitter (28), the polarization beam splitter (PBS) (32), the first power detector (38), and the second power detector (38) provide a first Mach-Zehnder interferometer (44).

14. The apparatus according to claim 11 or any one of the above claims 12-13,
further comprising a polarization setting tool (26) positioned in said first path for polarizing the first light beam (18, 19) in the given initial polarization.

15. The apparatus of claim 14,
wherein the polarization setting tool (26) is positioned in the path of the coherent light beam (6) before the first beam splitter (14).

16. The apparatus according to claim 13 or any one of the above claims 14-15,
wherein the polarization setting tool (26) linearly polarizes the respective beam (6; 18).

17. The apparatus according to claim 11 or any one of the above claims 12-16, further comprising:

- a third beam splitter (8) in the path of the coherent light beam (6) for splitting the coherent light beam (6) into a first initial light beam (10) travelling a first initial path and a second initial light beam (12) travelling a second initial path,

- a fourth beam splitter (16) in said second initial path for splitting the second initial light beam (12) in a fifth light beam (22) travelling a fifth path and a sixth light beam (24) travelling a sixth path,

- a fifth beam splitter (46) in said fifth and said sixth path for superimposing the fifth (22) and the sixth light beam (24) after each light beam (22, 24) has traveled a different path, to generate interference between the fifth (22) and the sixth light beam (24) in a resulting superimposed light beam (48) travelling a second resulting path,

a third power detector (50) in said second resulting path for continuously detecting the power of the resulting superimposed light beam (48) as a function of frequency when tuning the frequency of the coherent light beam (6) from a minimum to a maximum of a given frequency range, an output of the power detector (50) is connected via analog/digital-converter (42) with the evaluation unit for detecting any non-linearity in a tuning gradient frequency when tuning the frequency of the coherent light beam (6) from the minimum to the maximum of the given frequency range, and in case evaluation unit is detecting any non-linearity, the evaluation unit is using said detected non-linearity information to compensate effects on the detected powers of the third (34) and the fourth light beam (36) caused by said non-linearity.

18. The apparatus according to claim 11 or any one of the above claims 12-17, further comprising:
a tunable light source (4) for generating the coherent light beam (6).

19. The apparatus according to claim 11 or any one of the above claims 12-18, further comprising:

an analog/digital-converter (ADC) (42) connected with an output of the first detector (38) and connected with an output of the second detector (40) for converting the received analog data into digital data,

whereby the evaluation unit derives the transmissive properties of the optical device under test (2) from the frequency dependency of the detected and converted powers.

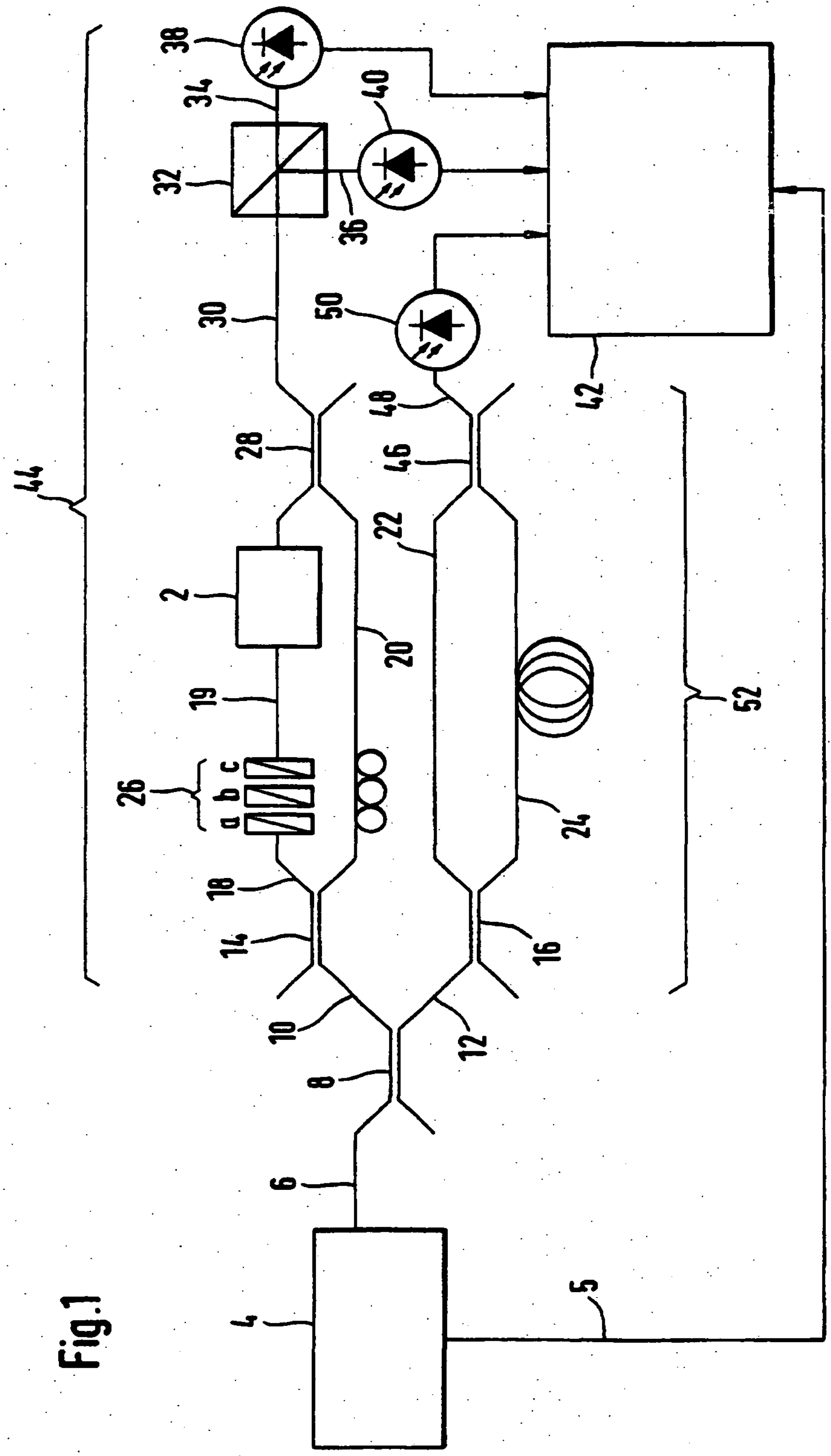
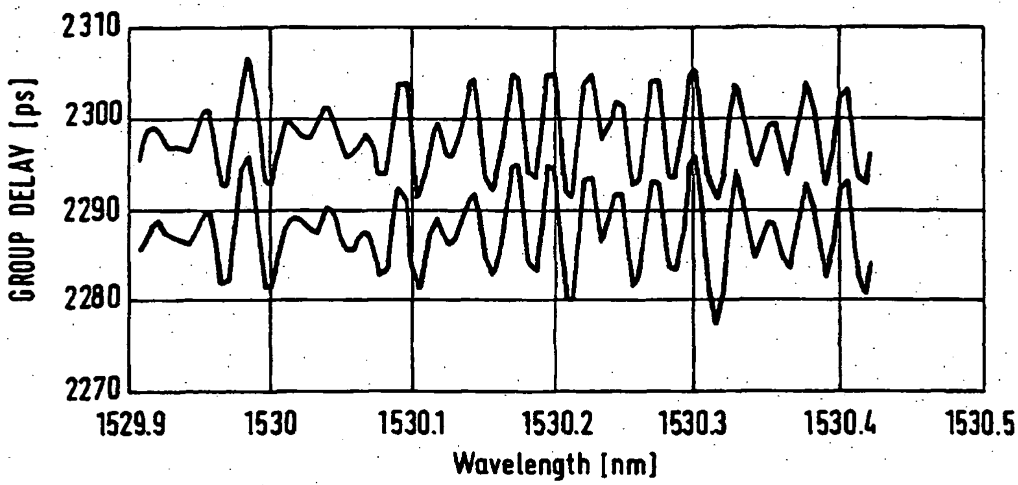

38
40
34
32
36
30
50
42
48
28
46
44
22
2
20
19
52
26
a b c
24
18
14
16
10
12
8
6
5
4

Fig.1

Fig.2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2300
2290
2280
2270
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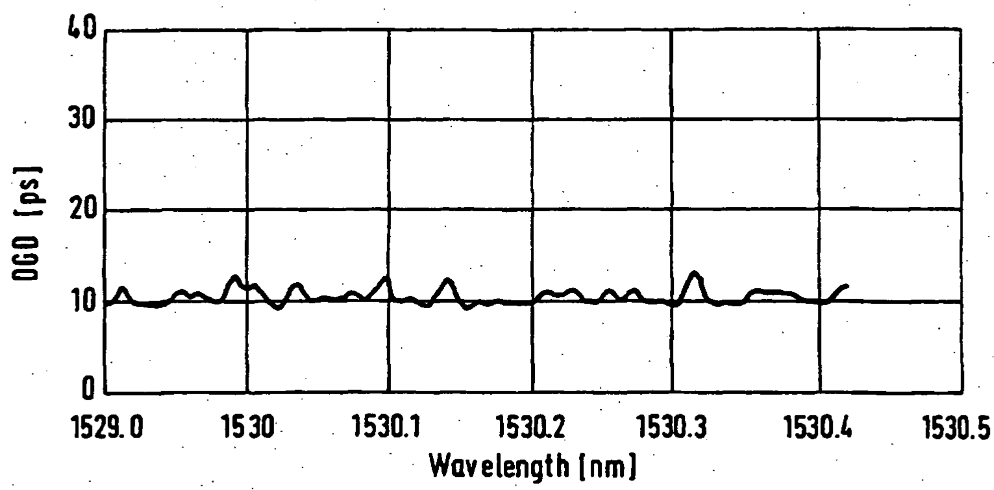
1530
1530.1
1530.2
1530.3
1530.4
1530.5
Wavelength [nm]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30
20
10
0
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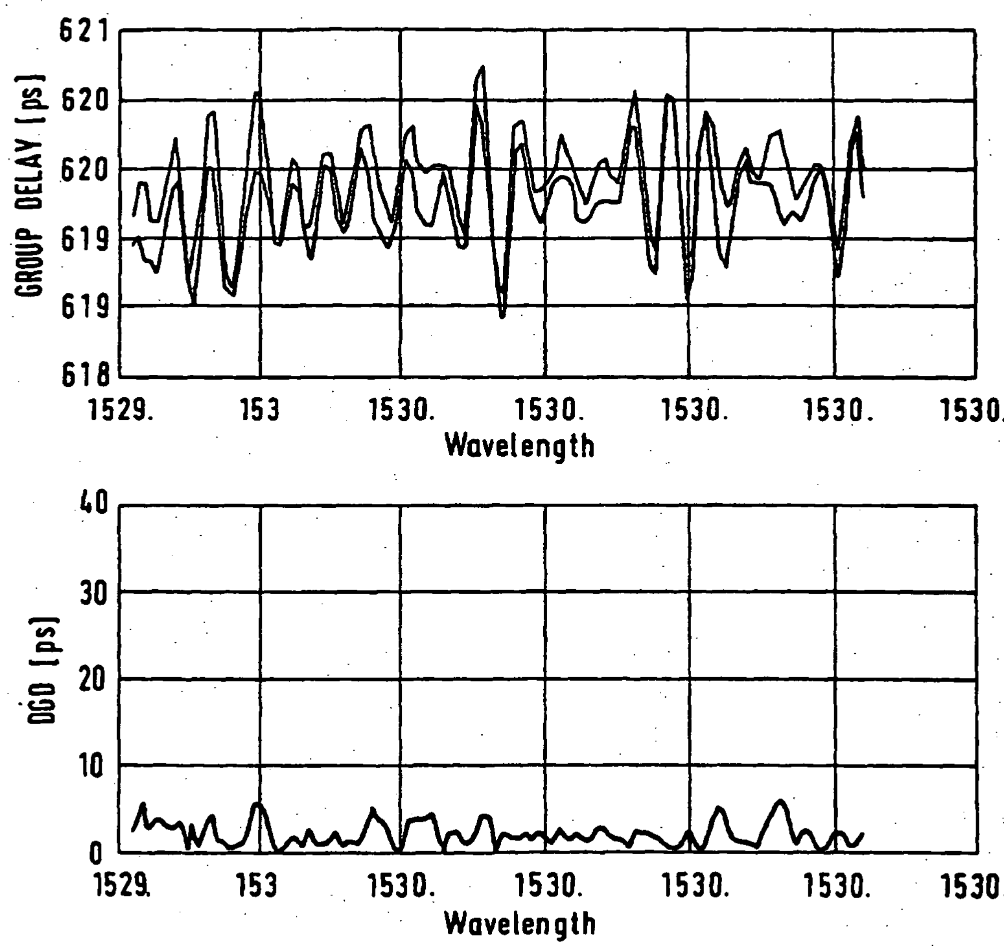
1530.1
1530.2
1530.3
1530.4
1530.5
Wavelength [nm]

Fig.3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620
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619
619
618
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153
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1530.
1530.
Wavelength
40
30
20
10
0
DGD [ps]
1529.
153
1530.
1530.
1530.
1530.
1530.
Wavelength

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 12 5089

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G01J
G01M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24 April 2001	De Buyzer, H

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